UNITED STATES ATOMIC ENERGY COMMISSION

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AN INVESTIGATION OF SPECIFICATIONS AND RATINGS OF COMMERCIAL AIR CLEANERS

Progress Report

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July 1, 1949

Harvard University

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Progress Report

July 1, 1949

AEC CONTRACT NO. AT-30-1-GEN-238

CONTRACTOR:

Harvard University
School of Public Health
Department of Industrial Hygiene
Boston 15, Massachusetts

G. S. Reichenbach, Jr., Leslie Silverman and Philip Drinker

This contract is between the United States Atomic Energy Commission New York Office of Directed Operations and Harvard University through the above department. It represents a fundamental and applied research project with the following purposes:

I. Consultation service on problems of dust and fume control and atmospheric pollution related to the operations of the New York Office.

II. Basic laboratory research on methods of increasing particle size and aggregation by condensation from sprays, Joule-Thomson effect, or other suitable means with particular application to methods of collecting low concentrations of aerosols.

III. In conjunction with the laboratory project, field studies of the performance of various dust and fume collectors were to be undertaken.

IV. A literature survey of unclassified domestic and foreign publications on dust and fume collection was also considered a necessary part of this project.

V. A survey of manufacturers data on dust collecting and air cleaning equipment was also made a part of this project because of its relationship to the applied problem.

Progress to Date

I. Consultation:

Under this phase of the project we have been available for consultation at any time a request has been made. Advice and service has been rendered with regard to Brush Beryllium Corporation, Harshaw Chemical Company and an AEC ore sampling plant. We have spent some time advising other AEC contractors such as Massachusetts Institute of Technology, the Kellex Corporation and Tracerlabs.

II. Basic research:

Under this phase of the project, considerable investigation has been made on use of sprays for air cleaning of light dust loadings. A progress report on this project is now being prepared and will be submitted at an early date.

III. Field studies:

The field study program has been hampered by limited personnel and funds but several installations have been contacted with regard to surveying and sampling this summer. Instruments for stack and effluent collection have been developed and assembled in preparation for this phase of the work.

IV. Literature survey:

The literature survey has been started and is still under investigation.

V. Manufacturers survey:

The results of the manufacturers survey and its relationship to test codes and their limitation is presented in the progress report attached to this summary of our activities to date.

Progress Report

July 1, 1949

An Investigation of Specifications and Ratings of Commercial Air Cleaners

G. S. Reichenbach, Jr., Leslie Silverman and Philip Drinker

Introduction

This report presents a study made to determine the type and scope of information available from manufacturers of air cleaning and dust collection equipment. Over forty manufacturers were contacted, principally those listed in the American Society of Mechanical Engineers, 1948 Mechanical Catalog.

To obtain as much specific information as possible and for ease in tabulating the data, specific forms were supplied to manufacturers (Figures 1 and 2). Limited data on general ventilation cleaners in 1940 was compiled by Carrier and others (1).

Air Cleaner Classifications

Commercial air cleaners may be grouped by usage into two basic categories:

A. Units for air cleaning installation in general ventilation systems (light dust loadings and high velocities (over 100 f.p.m.)).

B. Units controlling contaminants resulting from process equipment (heavy dust loadings with low to moderate velocities (3 to 50 f.p.m.)).

In certain instances there may be overlap of function when installation of general air cleaning devices are made for controlling (partially) dust generated by process equipment. Rarely, if ever, is the reverse of this true due primarily to the economics of the situation.

Each category may be sub-divided according to principle of collection as well as classification by usage.

I Mechanical:

(a) Settling chambers

1. Dry
2. Wet (Air Washers)

(b) Inertial separators

1. Dry
2. Wet

(c) Centrifugal

1. Simple

a. Dry
b. Wet

2. Multiple (Multiclone or Aerotec)

3. Mechanically driven

a. Dry
b. Wet

(d) Scrubbers

1. Simple
2. Mechanical drive

II Filters:

(a) Wet

1. Renewable or throw away
2. Continuous

(b) Dry

1. Renewable or throw away
2. Continuous

III Electrical:

(a) Dry
(b) Wet

In selection of air cleaners for a given installation, the design engineer must decide which characteristic of the cleaner is paramount or the limiting factor.

In many process installations, the collector acts as a separator for large economically valuable air-borne particles while valueless small particles are discharged through a stack. Ordinary low efficiency cyclones are a typical example.

An important limiting condition is the pressure loss created by the filter, especially for general ventilation system air cleaning because low static pressure fans are used in this type of installation.

For other cases the criterion is absolute cleanliness of the discharged air. Examples of this are found in the manufacture of photographic film, biologicals, and in the assembly of precision instruments.

Methods of rating filters have stemmed from these items and other considerations. The usual methods of rating filters include one or more of the following criteria:

1. Efficiency:

   (a) Weight removal (arrestance)
   (b) Weight removal by particle size
   (c) Discoloration of a paper test filter
   (d) Decrease in particle count

2. Pressure loss (initial and final or loaded)

3. Dust holding capacities

4. Air velocity or filtration area

Methods of Rating Air Cleaners

The importance of rating air cleaners has been recognized by several professional societies, notably the American Society of Mechanical Engineers (A.S.M.E.) and the American Society of Heating and Ventilating Engineers (A.S.H.V.E.). Of the foreign groups, the German Engineering Society (V.D.I.) also published a standard.

In order of their appearance in the literature or their establishment, they are as follows:

A. The A.S.H.V.E. established a Standard Code for Testing and Rating Air Cleaning Devices Used in General Ventilation (not for rating units to be used in the field of industrial hygiene) which was adopted in January 1934 (2).

   This code divided air cleaning devices into four groups according to pressure loss characteristics.

   Group A - Automatic type. In general all air cleaning devices which automatically maintain a constant resistance.

Group B - Low Resistance, Non-automatic type. Units designed for use where not more than 0.18 inch water gage pressure loss is allowable.

Group C - Medium Resistance, Non-automatic type. Units designed for use where not more than 0.5 inch water gage is allowable.

Group D - High Resistance, Non-automatic type. Units designed for use where 1.0 inch water gage or more is allowable as for the air intake of air compressors or internal combustion engines.

The dust loading was to be 0.35 grams of standard dust (50% by weight of powdered lamp black, containing 97.5% of free carbon minimum and having a bulking value of 3.5 pounds per cubic foot minimum. 50% by weight of ashes from Pocahontas bituminous coal screened to pass 200 mesh) for each 1000 cubic feet of air passed through the device.

Group A - 500 CFM (cubic feet per minute)

Group B - 250 CFM

Group C - 350 CFM

Group D - 350 CFM

The efficiency or arrestance was determined on a weight basis by determining the concentration of dust in the air with the cleaner in place and not in place. The arrestance is $1 - \frac{\text{concentration with cleaner}}{\text{concentration without cleaner}}$.

The weakness of this code was in the establishment of a "test dust". A change in the "test dust" was suggested in 1942 but was not accepted by the society and afterwards the code was withdrawn. Research is now in progress at the A.S.H.V.E. Research Laboratory (sponsored by air cleaner manufacturers) to recommend a new code for the society. This research is worthwhile but is directed toward the adoption of a "test dust" satisfactory to all interested parties.

B. In 1936 the German Engineering Society (Vereines deutscher Ingeniure) published its "Standard for Investigation of the Performance of Dust Removing Apparatus" (3). This publication was intended primarily for the use of specialists in conducting acceptance tests on industrial units, but was made comprehensive enough for all engineers to appreciate the problems involved and to realize the pertinent specifications needed for this equipment.

All efficiencies of the apparatus were to be determined after installation of the equipment and were to be conducted in a manner specified by this standard. Exceptions and alternative procedures are based on agreement between the purchaser and supplier. Features covered include:

I. The defining of dust composition with regard to the free falling velocity of the particles.

II. Location of sampling areas in ducts.

III. Sampling devices utilizing a suitable cyclone alone or in conjunction with a filter material.

IV. Optional methods of determination of the degree of dust removal (weight basis).

(a) From the dust quantity deposited in the remover and the dust content of the cleaned gas.

(b) From the dust quantity deposited in the remover and the dust content of the raw gas.

(c) From the dust contents of the raw gas and the clean gas.

V. Emphasis was laid on the need for the specifications of dust content to be maintained in the clean gas as well as specification of percentage dust removal.

C. After seven years of committee research and investigation, the American Society of Mechanical Engineers in 1941, established a Test Code for Dust-separating Apparatus (4). In essence this code is similar to that of the V.D.I. in that it specifies testing equipment after its installation and gives several methods of sampling for this purpose. Neither code can be considered as practicable for routine testing of production units for selection purposes.

D. Other organizations have evolved methods of testing air cleaners of which the most notable is that employed by

the National Bureau of Standards (5). This method of rating utilizes a photometric method for determining efficiency and contains the following procedures:

"(1) Drawing air contaminated with test dust through the cleaner.

(2) Drawing samples of cleaned and uncleaned air simultaneously through filter papers high efficiency (100%).

(3) Comparing the two so obtained by means of a photometer using transmitted light.

(4) Changing the air flow per unit area of the spots during successive runs until they are equal or approximately equal in density.

(5) Computing the efficiency or arrestance on the basis of air flow upstream and downstream."

This method of testing has been used by many governmental agencies as a criterion in the purchase of air cleaning devices.

E. In 1926 the U. S. Bureau of Mines established (6) a routine testing method for gas mask filters which matched the intensity of a Tyndall beam from the effluent smoke with that of a known smokiness. This method has since been superseded by Schedule 21 (7) which utilizes the determination of the amount of material passing a filter during a given time at a known loading. This work

was all limited to respirator and gas mask filters.

Hill (8) published a method of rating respirators and filters which was used in England by the Chemical Defense Center at Porton. This was also a photoelectric method in which carbon black was the suspensoid used.

The methods of testing filters discussed are limited in their application to the overall problem of testing air cleaners. For this reason certain organizations such as the Eastman Kodak Company (9), Bell Telephone Laboratories (10) and Consolidated Edison Company of N. Y. (11,12) have developed their own testing procedure and methods of rating.

Test Dusts

A basic deficiency of the present proposed methods of rating air cleaners is that there has been no unanimity regarding the type of material to be used as a test suspension.

Early tests made on filters for general ventilation used ordinary household dust. This was later superceded because of non-uniformity and the fact that such settled dusts are easily filtered. The test dust of the original A.S.H.V.E. proved unsatisfactory because of lack of evidence that the suspensions were comparable to those met in practice and disagreement as to a satisfactory substitute led to withdrawal of the code.

The codes of the German Engineering Society (3) and the A.S.M.E. (4) avoid use of a specific test dust by measuring the per-

formance of the air cleaners after installation. This is a more fundamental way to test cleaners but is expensive and yields results influenced by the character of the material which the collector is removing.

The N.B.S. test method (5) uses a test dust composed of a Cottrell precipitate procured from one source, a local power plant burning pulverized coal. A modification since the original specification has been the addition of 4% lamp black to 96% of the precipitated fly ash.

Many other test dust have been suggested notably those by Rowley and Jordan (13,14,15,16,17), Dalla Valle (18), Stern (19), Farr (20) and Hill (8). Recommendations varied from the use of one specific particle size and composition dust to the application of bacteria as suggested by Dalla Valle. During World War II the U. S. Army used dust obtained from the A. C. Spark Plug Company, Flint, Michigan. The Eastman Kodak Company and Bell Telephone Laboratories use atmospheric air for their testing media. In all cases there are pertinent reasons for the selection of the dust, contingent upon which properties of the cleaners were desired to be rated.

There is little prospect of accord at the present time between manufacturers and consumers of air cleaning devices concerning the possible selection of a standard test dust because of the emphasis which the inherent characteristics of the dust may play in favor of one or another device. Dibble (21) in 1925 pointed out the varying efficiencies of dry air filters for various types of dust.

Discussion of Manufacturers Data as Supplied from Questionnaire

Table 1 is a tabulation of the information obtained by the method outlined earlier in the report.

The equipment is listed according to the classifications as to usage and basic principle of operation. Units with the exception of those with definite volume limitations as noted in the table may be supplied or constructed to handle the desired air volumes. Flows cited correspond to the reported test results.

For reasons given previously, the material removed, its particle size and the basis of efficiency determinations make performance comparisons of the various units difficult. The remarks include the pertinent points of uniqueness or obvious deficiencies of the equipment from the A.E.C. standpoint.

The two most important factors in determining the needs of the A.E.C. with regard to air cleaners for radioactive air-borne wastes are absolute cleanliness of the effluent air and minimum maintenance. Information on particle size range of radioactive wastes is limited at the present time, hence the cleaner should remove the maximum amount possible for all size particles. Installations should perform with high and constant efficiencies with a minimum of maintenance and a maximum useful life before replacement. With regard to the removal of non-radioactive air-borne particles, it is felt that the present status of information regarding the efficiencies of col-

lectors is too sketchy to enable the designer to rigorously select the most economically satisfactory unit for a particular application.

At the present time, to our knowledge, the A.E.C. has not adopted a standard method of testing air cleaning devices prior to or after installation although it is and will continue to be a large purchaser of such equipment. It is therefore essential that specifications for air cleaners should be formulated for all types of problems in A.E.C. installations. The first part should embrace a suitable comparative testing basis for devices submitted by interested manufacturers. This test would be utilized as a screening device and units not satisfying these requirements would receive no further consideration, unless the units were modified.

The second specification would be similar in nature to the A.S.M.E. code although modified for the particular needs of the A.E.C. (such as setting a limit for the effluent concentration) and would be used for the acceptance of an installation as furnished by the manufacturer or contractor.

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HARVARD UNIVERSITY
SCHOOL OF PUBLIC HEALTH

DEPARTMENT OF INDUSTRIAL HYGIENE

55 Shattuck Street
Boston 15, Massachusetts

Gentlemen:

A research program is being initiated in our department on the efficiency of air cleaning devices.

Our primary interest is in the cleanliness of the effluent air rather than the percentage efficiency.

Before starting our test program in our laboratory, we are polling the manufacturers of air cleaning units listed in the 1948 A.S.M.E. Directory.

The data which we receive will be tabulated. After critically reviewing the data, we shall then have a base line upon which to expand the data in this field.

For convenience we are enclosing forms which we would appreciate having your staff complete with respect to each of the types of equipment manufactured by your organization.

For our future reference, we should like to have any literature pertaining to this equipment.

We are grateful for your cooperation in this project.

Very truly yours,

George S. Reichenbach, Jr.

George S. Reichenbach, Jr.
Research Associate

GSR/ms
Enclosures

AIR CLEANING RESEARCH PROGRAM

1. Name of Manufacturer ______________________________

2. Address ______________________________

3. TRADE NAME of Equipment ______________________________

4. Field or Laboratory Test ______________________________

5. Material Removed ______________________________

______ Chemical Composition ______ Particle Size Range ______

6. Overall Efficienoy:

Weight Basis ______ Discoloration ______ Particle Count ______ Other ______

7. Quantity of Gas Handled ______________ Temperature ______

8. Velocity of Gas Through Unit ___ Initial ______ Loaded ______

9. Pressure Loss Through Unit ___ Initial ______ Loaded ______

10. Efficiency of Separation According to Size of Particle:

Size ______________ Efficiency ______________

______________ ______________

______________ ______________

______________ ______________

______________ ______________

______________ ______________

______________ ______________

11. Concentration of Dust at Inlet and Outlet of Unit:

Inlet Concentration ______________ Outlet Concentration ______________

______________ ______________

______________ ______________

FIGURE II

TABLE 1

DATA REPORTED BY MANUFACTURERS OF AIR CLEANING DEVICES

Type	Manufacturer Trade Name	Gas		Material Removed	
		CFM	Temp °F	Comp.	Size
Mech.	Air-Maze Corp. Air-Maze P - 5	1170 for 20'x20' panel	Room	N.B.S Dust 96% Cottrell 4% Lint	
Mech.	Air-Maze Corp Air-Maze P - 18	1180 for 20'x20' panel	Room	Same	
Elect.	Air-Maze Corp. Electro-Maze	300 for 1' panel	Room	Same	
Elect.	American Air Filter Co. Electro-Matic	1600	Room	50% smoke carbon	1/4μ
Elect.	American Air Filter Co. Electro-Cell	795	Room	35% siliceous 5% coal dust	
Elect. Mech.	American Air Filter Co. Electro-Air Mat	625	Room	3% fi- brous 7% misc.	50μ
Cloth	Coppus Engineering Corp. Type FU	1 (lab)	Room	Cottrell ppt	<1μ
Mech.	Dollinger Corp. Stay new type HE	--	--	N.B.S Dust	
Mech.	Farr-Company Farr-Air type 44	1200	Room	Stand. Army Fine Test Dust	50% <5μ
Elect.	Westinghouse Electric Co. Industrial Precipitron	100,000	120°F	Atmos. Dust	
Mech.	Hudson H. Bubar Co. Type S	100,000	--	Fly ash	85% <325m
Mech.	Buell Engineering Co. Van Tongeren Cyclone	300 +	350	Spec. Grav.2.0	0-5μ
Wet. Mech.	Buffalo Forge Co. scrubber	2000- 3000	200	Elec. Furn. Fume	0.2μ
Wet. Mesh.	Wet glass cell air washer	--	--	--	>10μ

Efficiency Basis	%	Unit Characteristics Velocity FPM	P.D."H_2O	Remarks
Weight	93-96	519	0.08	All metal - cleanable adhesive coated
Weight	96-99	500	0.25	All metal - Cleanable adhesive coated
Discolor	90	300	?	Viscous coat optional
Weight Discolor	99+ 95	300	0.17	Self-cleaning continuous precipitator
Count	1/4-1μ-85 1-2μ-90	300	0.15	Can be furnished with cleaner.
Count	1/4-1μ 85 1-2μ-90	35	0.12 init.	Electrostatic - Filter paper
Discolor	85	50	0.26	Cleanable pleated filter cloth
Discolor	80	500	0.40	Automatic self-cleaning viscous filter
Weight	95	519	0.12	Viscous coated metal
Discolor	90	300-400	0.1	Periodic washing needed
Weight	80	--	0.06	Continous cleaning inertial separator
Weight	49	3000	--	Low maintenance cyclone of improved design
Weight	99.97	--	20±	High static press. drop
Count	90	--	--	General ventilation ordinarily

Type	Manufacturer Trade Name	Gas		Material Removed	
		CFM	Temp °F	Comp.	Size
Wet Mech.	Duncan-Hudson Company Fog-Filter	4500	180	Acid Fumes	0-5μ
Mech.	Green Fuel Economizer Co. Cindertrap	as required	to 700	Cinders	<325m
Mech.& Cloth	Ideal Industries Ideal	500	Room	Sand	22-66μ
Elect.	Koppers Company, Inc. Kopper-Elex	as required	to 1000	--	--
Mech.	Leiman Bros., Inc. 567-A	1210	Room	Grinding Dust	5-10μ
Mech.	B & S Fabricators Linderoth Aerodyne	3280	Room	SiO_2 parting cmpd.	<10μ
Cloth	Pangborn Company	as required	to 165	Dry Dust	varies
Wet Mech.	Pease Anthony Equip. Co. Venturi-Scrubber	as required	600°F	Iron Fume	0.015 -15μ
Wet Mech.	Schmeig Industries, Inc. Centr-Merge	300	70-300	Na_2CO_3 Dust	--
Wet Mech.	Claude B. Schneible Multi-Wash	(Lab) 28.9	129	Foundry Dust	<15μ
Cloth	W. W. Sly Company Dust-Filters	as required	200	Varied	<0.5μ
Mech.	Thermix Corporation Aerotec	as required	1000	Tooth-powder	<325m
Elect.	Trion, Inc. Electric Air Filters	as required	--	--	--
Elect.	Western Precipitation Co. (Cottrell)	100,000	--	Varied	--

Efficiency		Unit Characteristics		Remarks
Basis	%	Velocity FPM	P.D. "H_2O	
Weight	91	--	2-4	All models in development stage
Weight	30	1200	0.1-0.3	Nuisance eliminator for cinders
Weight	97.4 for 22μ	166	--	Unit type collector only
Weight	to 99.9	Varied	0.5 Max.	---
--	--	--	2.0	Unit type collector only
Weight	95	--	--	U. S. models in development stage
Weight Count	98 outlet <10MPPCF	Varies	Varies	Baghouse installations
Weight	95.5 -99.7	--	14-16	Several installations some in development stage
Count	inlet 30MPPCF outlet 0.6MPPCF	2000	5.5	Wet collector
Count	inlet 99.7MPPCF outlet 11MPPCF	3300	4.0	Wet cyclone plus wet impingement plates
Weight	99+	2	2-4	Baghouse installations
Weight	97.7	--	--	Small radius cyclones
Discolor	99.5	--	--	Recent design electrostatic precipitator
Weight	99.9+	Varied	--	Proven cottrell precipitator

END OF DOCUMENT